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Controlling Legionella in Hospital Water Systems: Experience with the Superheat-and-Flush Method and Copper-Silver Ionization

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# CONTROLLING *LEGIONELLA* IN HOSPITAL WATER SYSTEMS: EXPERIENCE WITH THE SUPERHEAT-AND-FLUSH METHOD AND COPPER-SILVER IONIZATION

Janet E. Stout, PhD; Yu-Sen E. Lin, MS; Angella M. Goetz, MNEd; Robert R. Muder, MD

## ABSTRACT

**OBJECTIVE:** To evaluate the effect of copper-silver ionization on *Legionella* colonization and nosocomial legionnaires' disease and to compare the efficacy of metal ions versus the superheat-and-flush method of disinfection.

**DESIGN:** Prospective determination over a 36-month period of copper and silver ion concentrations in the recirculating hot-water system, *Legionella* colonization of the hospital water distribution system, and cases of nosocomial legionnaires' disease. Retrospective comparison of results with the previous 13 years, during which the superheat-and-flush method was used.

**SETTING:** The Pittsburgh Veterans' Affairs Health Care System (University Drive Division) acute-care hospital.

**INTERVENTION:** Three copper-silver ionization systems were installed on the hot-water distribution system in November 1994.

**RESULTS:** The average number of cases of legionnaires' disease per year and the percentage of distal sites positive for *Legionella pneumophila* for the superheat-and-flush method versus the copper-silver ionization method was six cases with 15% positivity versus two cases with 4% positivity, respectively. The reduction in *Legionella* colonization after copper-silver ionization was significant ( $P < .05$ ) compared to the superheat and flush. Mean copper and silver ion concentrations (mg/L) were 0.29 and 0.054 from hot-water tanks, and 0.17 and 0.04 from distal outlets, respectively.

**CONCLUSIONS:** We conclude that a properly maintained and monitored copper-silver ionization system was more effective than the superheat-and-flush method for reducing the recovery of *Legionella* from the hospital water distribution system (*Infect Control Hosp Epidemiol* 1998;19:911-914).

Since 1981, the Pittsburgh Veterans' Affairs Medical Center has used the superheat-and-flush method to control *Legionella pneumophila* in the hospital water distribution system.<sup>1</sup> This practice halted an outbreak; however, sporadic cases of nosocomial legionnaires' disease have continued to occur (Figure 1). After 10 cases of nosocomial legionnaires' disease were diagnosed from November 1993 to November 1994, we instituted a new eradication method.

Copper-silver ionization systems were installed on the hot-water recirculating system. This system electrolytically generates copper and silver ions, which bind to the bacterial cell wall causing cell-wall disruption and lysis.<sup>2</sup> We previously demonstrated the efficacy of this method in controlling *Legionella* both in vitro and in a non-acute-care hospital setting.<sup>3,4</sup> This study was undertaken to evaluate the efficacy of the copper-silver ionization system in an acute-care hospital experiencing sporadic cases of nosocomial legionnaires' disease.

Our objectives were to (1) determine the effect of copper-silver ionization on *Legionella* colonization of the hospital water distribution system; (2) determine the effect of copper-silver ionization on the incidence of nosocomial legionnaires' disease; and (3) compare the efficacies of two *Legionella* eradication methods, copper-silver ionization

versus superheat-and-flush, for controlling *Legionella* colonization and nosocomial legionnaires' disease.

## METHODS

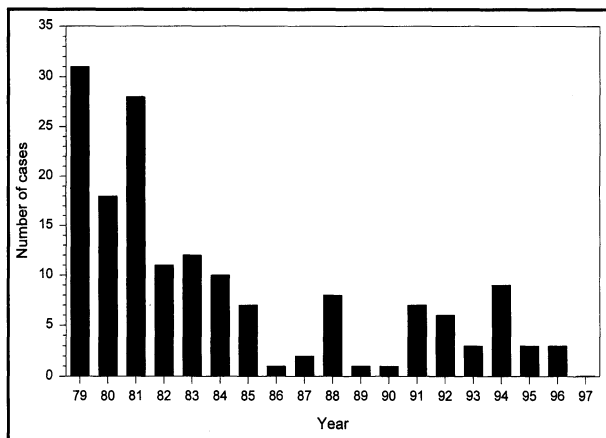
The Pittsburgh Veterans' Affairs Health Care System, Oakland Division, is a 550-bed acute-care facility. Hot water is supplied to the basement through the 9th floor from two large-volume (2,000 gal) hot-water storage tanks. The 9th through 11th floors are supplied by two smaller-volume (1,000 gal) hot-water storage tanks. In 1987, the A wing was added to the hospital. This wing has a separate hot-water system that maintains water at 140°F by semi-instantaneous hot-water heaters. No cases of nosocomial legionnaires' disease have been associated with this wing of the hospital.

### *Legionella* Eradication Methods

**Intermittent superheat and flush.** Beginning in July 1981, when cases of nosocomial legionnaires' disease were detected or when  $\geq 30\%$  of environmental surveillance sites were positive for *Legionella*, the temperature of the hot-water storage tanks was raised to 60° to 77°C, and outlets were flushed for 20 to 30 minutes.<sup>1</sup>

**Copper-silver ionization system.** In November 1994, copper-silver ionization systems were installed on the hot-water

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**FIGURE 1.** Pittsburgh Veterans' Affairs Medical Center. Number of cases of nosocomial legionnaires' disease per year from 1979 to 1996, superheat-and-flush procedures were instituted in July 1981. The copper-silver ionization system was installed in November 1994.

distribution system. The ionization system consists of a flow cell containing metal electrodes and a controller to direct current through the flow cell (Liqui-Tech, Inc, Willowbrook, IL). Each of two large-volume hot-water storage tanks had a dedicated controller and flow cell placed on a recirculating loop that moved water from the bottom of the tank, through the flow cell and back into the top of the tank. One controller and flow cell was placed on the return hot-water recirculating line before the water returned to the two smaller storage tanks. Amperage was set at 3.0 A for the first 3 months of operation, 2.0 A for the next 5 months, and 3.0 A thereafter.

#### Case Detection and Definition

A case of nosocomial legionnaires' disease was defined as pneumonia with onset of symptoms more than 48 hours after admission and a positive result for one or more of the following tests: culture of respiratory secretions on *Legionella*-selective buffered charcoal yeast extract agar, direct fluorescent antibody staining of secretions, urinary antigen testing by radioimmunoassay (Binax, South Portland, ME), and *Legionella* serology by the enzyme-linked immunosorbent assay method (a single elevated titer to  $\geq 1:256$  or a fourfold rise in titer to  $\geq 1:128$ ). Subtyping of patient and environmental isolates of *L pneumophila* serogroup 1 was performed by monoclonal antibody analysis (courtesy of Jean R. Joly, MD).<sup>5</sup> Pulsed-field gel electrophoresis was performed, as previously described, on clinical and environmental isolates recovered in 1995 and 1996 only.<sup>6</sup>

#### Environmental Surveillance

Environmental cultures for *Legionella* were collected from the same 14 distal sites (faucets and showers) and all hot-water storage tanks every month from 1981 to 1988 and then every other month thereafter. Cultures were performed as previously described.<sup>7</sup>

#### Monitoring the Copper-Silver Ionization System

Copper and silver ion levels were monitored by atomic absorption spectrophotometry performed every 1

to 2 weeks for the first 2 months of operation and then monthly for the first year. Thereafter, samples were tested every other month, coinciding with *Legionella* environmental monitoring. Copper also was monitored weekly using a copper test kit (model STC-CTP; LaMolte Chemical, Chestertown, MD). Hot-water samples were collected from the hot-water tank drains after flushing the line and from ward bathroom sinks on the fourth and ninth floors.

## RESULTS

### Cases of Legionnaires' Disease

The average number of cases of nosocomial legionnaires' disease was 25 per year in the 3 years before instituting the heat-and-flush procedure; 6 per year throughout the 13 years when the heat-and-flush procedure was performed; and 2 per year in the 3 years after installing the copper-silver ionization system (Figure 1, Table). Monoclonal antibody subtyping demonstrated that patient strains of *L pneumophila* serogroup 1 were identical to isolates recovered from the hospital water system.<sup>5</sup> From 1980 to 1997, there were 71 culture-confirmed cases of legionnaires' disease due to *L pneumophila* serogroup 1. Monoclonal antibody subtyping of these isolates showed that 56 were subtype Allentown, 10 were Philadelphia, 4 were Bellingham, 1 was Oxford, and 1 was subtype OLDA. Isolates of both Allentown and Philadelphia subtypes were recovered from one patient. Throughout this same period, isolates of *L pneumophila* serogroup 1 recovered from the hospital water system were identified as monoclonal subtypes Allentown, Philadelphia, and Bellingham. Epidemiologically linked patient and environmental strains also were matched genotypically using restriction endonuclease analysis with pulsed-field gel electrophoresis. Pulsed-field gel electrophoresis was performed on the isolates recovered from the patients in 1995 and 1996 and also confirmed nosocomial acquisition.

### Environmental Surveillance

The change in recovery of *Legionella* from distal sites and hot-water storage tanks is depicted in the Table and Figure 2. The hot-water storage tanks became negative for *Legionella* only after treatment with the copper-silver ionization system. Distal-site positivity also was reduced from 14% to 4% after copper-silver ionization ( $P < .05$ ).

### Monitoring the Copper-Silver Ionization System

Atomic absorption testing for copper and silver ions was performed on 110 hot-water samples from the hot-water tanks and 60 samples from ward faucets. Mean copper and silver concentrations (mg/L) were 0.29 and 0.054 and 0.17 and 0.04, respectively.

## DISCUSSION

*L pneumophila* in the water distribution system of hospitals is the source for the majority of cases of nosocomial legionnaires' disease.<sup>8-10</sup> Control of nosocomial outbreaks has been accomplished by disinfecting the hospital water distribution system. Superheat and flush and hyperchlorination have been successful at halting outbreaks;

**TABLE**  
EFFICACY OF TWO DIFFERENT ERADICATION METHODS ON *LEGIONELLA* COLONIZATION AND CASES OF NOSOCOMIAL LEGIONNAIRES' DISEASE

Eradication Method	Time Period	<i>Legionella</i> Cases (Avg/Y)	% of Environmental Surveillance Sites Positive (N)*	
			Distal Sites	Hot-Water Tanks
None	1979-1981	25	50% (90)	100% (30)
Heat and flush	1981-1994	6	14% (1,345)	46% (383)
Copper-silver ionization	1995-1998	2	4%† (270)	0%† (72)

\* N = Number of samples tested.

† Statistically significant decrease,  $P < .05$ , chi-square test.

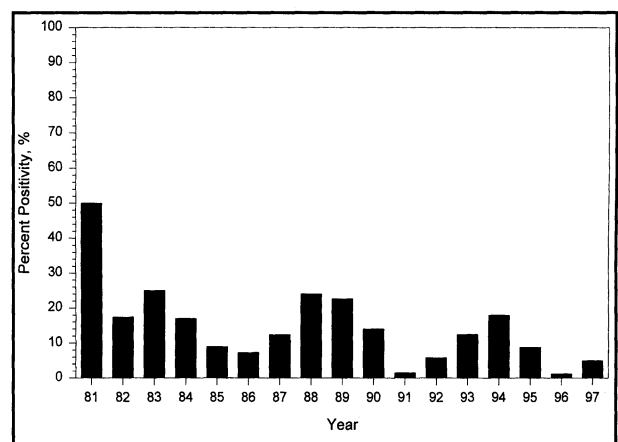
however, neither method is ideal. Long-term use of hyperchlorination leads to severe corrosion of the distribution pipes. Elevated levels of carcinogenic by-products of chlorine have been linked to cancer and associated with higher rates of miscarriages in pregnant females.<sup>11,12</sup> Intermittent use of the superheat-and-flush method is logistically difficult, labor-intensive, and time-consuming. Scalding is a potential hazard, although such incidents have not occurred in our 13-year experience. We examined the efficacy of copper-silver ionization as an alternative disinfection method for controlling nosocomial legionnaires' disease.

This is our second report in which copper-silver ionization has proven effective in controlling *L pneumophila* in a hospital water distribution system.<sup>3</sup> Copper-silver ionization appeared to be more effective than the superheat-and-flush method for reducing *Legionella* colonization of the hospital water distribution system (Table).

One weakness of this study is that conditions during the two periods may not have been comparable. Thus, studies from other hospitals using copper-silver ionization as the primary disinfection modality are needed to verify our conclusion. A study by Mietzner et al has been performed, and they similarly concluded that copper-silver ionization was superior to thermal treatment for controlling *Legionella* in the plumbing system of their hospital.<sup>13</sup>

Mean copper and silver levels in our hot-water system did not exceed Environmental Protection Agency-recommended levels for drinking water, and no problems with water quality were reported. Maintenance of the ionization system is important, as demonstrated by the fact that mechanical failure of a recirculating pump was temporally related to the occurrence of two cases of legionnaires' disease in the fall of 1995.

Despite the use of copper-silver ionization, some cases of legionnaires' disease occurred. It appears that it may be unrealistic to expect that any disinfection method can prevent every case of hospital-acquired legionnaires' disease. This is probably due to the following: (1) every method is subject to mechanical or human failure; (2) the complexities of large water distribution systems make it difficult to assure effective treatment of the entire system; and (3) exposure of high-risk patients to even low concentrations of *L pneumophila* may result in disease. Recognizing the limitations of a retrospective comparison and the changes in patient population over



**FIGURE 2.** Percentage of distal outlets positive for *Legionella pneumophila* serogroup 1 per year from 1981 to 1997. Environmental monitoring of distal sites and four hot-water tanks was performed monthly until 1988 when bimonthly surveillance began.

the course of this study, there appeared to be a trend toward a reduction in nosocomial legionellosis following the installation of the copper-silver ionization system. Not only was there a reduction in the number of cases in 1995 and 1996, there were no cases of nosocomial legionnaires' disease detected in all of 1997. This was the first time that no cases were diagnosed in a 1-year period since we began looking for cases in 1979 (Figure 1). This reduction in the number of cases was not due to reduced surveillance for the disease; the average number of *Legionella* urinary antigen tests performed in the 3-year period from 1992 to December 1994 was 316, compared to 378 from January 1995 to December 1997.

The approximate cost for installation of three copper-silver ionization systems at this hospital was \$70,000. Maintenance costs were minimal. Electrode replacement is expected after 2 to 3 years at an estimated cost of \$2,000 per flow cell. For comparison, the cost of a single heat-and-flush procedure for one community hospital was estimated at \$20,000,<sup>14</sup> due primarily to overtime costs. Installation of continuous hyperchlorination equipment at one facility was estimated to cost approximately \$75,000, with annual costs of \$7,000.<sup>14</sup>

For hospitals with documented nosocomial legionellosis, particularly those with transplant patients, the copper-silver ionization system appears to be a cost-effective

alternative to hyperchlorination and thermal disinfection for the control of nosocomial legionnaires' disease in healthcare facilities. Vigilance for cases of legionnaires' disease, routine environmental cultures for *Legionella*, and monitoring of ion levels should continue as part of the Infection Control Program to document efficacy or detect problems with the system. We perform *Legionella* environmental monitoring and copper-silver analysis every other month. If *Legionella* culture is performed in-house, the costs for supplies and media would be less than \$1,000 per year. Ion analysis should be performed by atomic absorption spectrophotometry. The copper test kit provided with the ionization system offers only a crude estimate of copper concentration and no information on silver levels. Monitoring for silver is important, because elevated silver ion concentrations can cause discoloration of the hot water due to precipitation of silver chloride. For our hospital, the cost for copper and silver analysis for 1 year was approximately \$2,000.

In summary, copper-silver ionization was more effective than superheat and flush in reducing *Legionella* colonization. If properly monitored, it does not affect water quality adversely and is comparable in cost to hyperchlorination. However, regular monitoring and maintenance of the system is required for optimal efficacy. Our data supports the opinions expressed by Goetz and Yu<sup>15</sup>; the apparent technical advance and efficacy of copper-silver ionization should be viewed with optimism, albeit restrained.

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## Antimicrobial Threat Discussed

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Martin S. Favero, PhD

On September 9-10, 1998, more than 300 representatives of political, expert, consumer, and producer groups attended a meeting held in Copenhagen to discuss the worldwide threat of resistance. Professor Fernando Baquero of the Center of Microbiology in Madrid said that bacterial resistance may return us to the age before antibiotics.

It was noted that some European countries have a daily consumption of more than a ton of antibiotics for both human and animal treatment. Recent figures for methicillin-resistant *Staphylococcus aureus*, for example, indicate that resistance is developing rapidly both within and outside Europe. In 20

surveyed centers around the world, only four Nordic countries (Denmark, Finland, Norway, and Sweden) had MRSA resistance levels below 2%. It was between 5% and 20% in Germany, Lithuania, Colorado US, New Zealand, Australia, France, and the United Kingdom. In five centers (California US, Spain, Belgium, Kuwait, and South Africa), it was between 20% and 40%, and in four centers (Poland, New Jersey US, Malaysia, and Greece), it was over 40%.

Reasons for the low rates in Scandinavia are because of the efforts to insulate their country. All patients and hospital staff who have been hospitalized or worked outside Scandinavia are isolated on arrival at a Scandinavian hospital until it is confirmed that they are not colo-

nized with multidrug-resistant bacteria.

Conference attendees called for national and global plans to address the threat. Currently, WHO is trying to implement global coordination of efforts. The conclusions of the five workshops held at the conference are available on the conference web site at <http://www.microbial.threat.dk>.

The September 5, 1998, issue of the *British Medical Journal* contains a series of articles on antimicrobial resistance that were published in conjunction with the conference. The series of articles discusses the perceptions of the public's right for treatment, controversies in measures to reduce use, the need for education of the public and physicians, and international surveillance.